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Investigation of VARIOUS ACTIVATOR REFRACTORY SUBSTRATE COMBINATIONS

J. H. Affleck

Power Tube Department
General Electric Company
Schenectady 5, New York

Contract No. AF 19(628)-279
Project No. 4619
Task No. 461901

Scientific Report No. 4
December 27, 1962

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Prepared
for

ELECTRONICS RESEARCH DIRECTORATE
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS

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ABSTRACT

Cathode life tests are continuing in excess of 10,000 hours. A method has been devised to display the retarding potential characteristic which permits the rapid determination of the work function. Preliminary results using the General Electric Partial Pressure Analyzer to study cathode processing and poisoning are discussed.

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INTRODUCTION

During the past quarter, the life tests have continued on the barium orthosilicate dispenser cathodes. Efforts to put the General Electric Partial Pressure Analyzer into operation have not been entirely successful. However, some preliminary results have been obtained and are discussed below.

A method for displaying the retarding potential characteristic (log i vs V) has been tested, and initial data indicates that this method compares favorably with the conventional technique of point-by-point plotting.

EXPERIMENTAL RESULTS

Since 1 October 1962 the following results have been obtained:

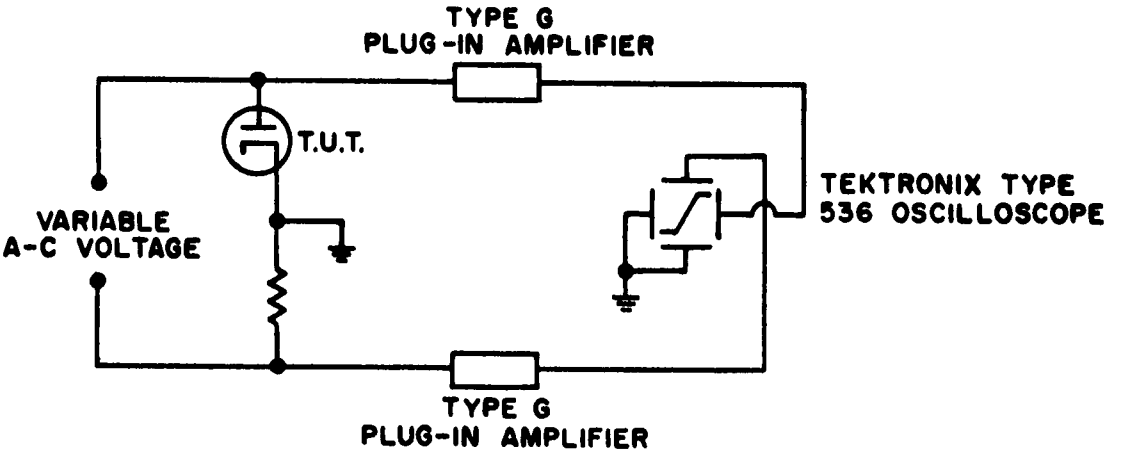
1. Life Tests

Two dispenser cathodes, each consisting of a tungsten matrix with barium orthosilicate dispersed throughout the pores of the matrix, have been on life test for over 10,000 hours. These cathodes are operating at a temperature of 1075°C under space charge limited conditions drawing a d-c current density of 0.5 a/cm^2 and 1 a/cm^2. Efforts are being made to perform additional tests at higher current levels by providing an anode capable of handling the increased anode dissipation.

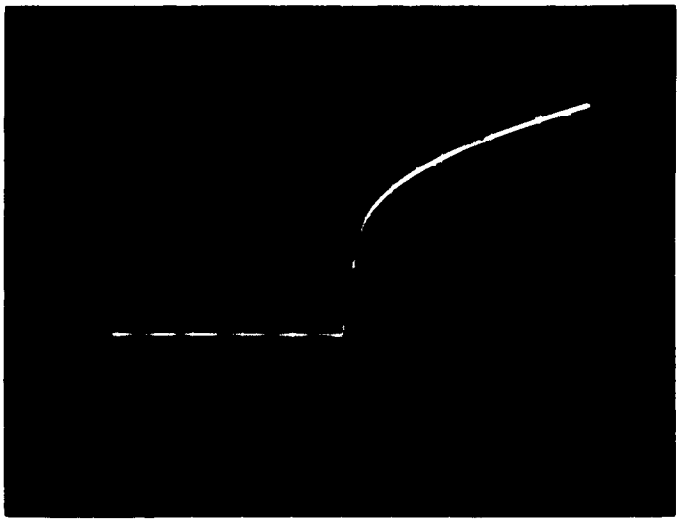
2. Retarding Potential Characteristic

During the course of this investigation, the i vs V characteristic has been displayed on an X-Y oscilloscope (Tektronix Type 536) so that changes in the thermionic properties of a cathode during processing can be observed. This has been extremely helpful in noting the immediate effects of changes in cathode or anode temperature as well as poisoning phenomena. The circuit used for the i vs V characteristic is shown in Figure 1a while a typical trace obtained using this circuit is shown in Figure 1b.

Although this type of display has been found to be very useful, it does not provide a very convenient means for determining the zero field emission (I_o).



a. Circuit for i vs V Characteristic



b. Typical Trace Obtained Using Circuit Above

Figure 1

Therefore, a method has been devised to display a portion of the retarding potential curve on an oscilloscope. This method permits the rapid evaluation of the cathode work function without the necessity of a point-by-point plot.

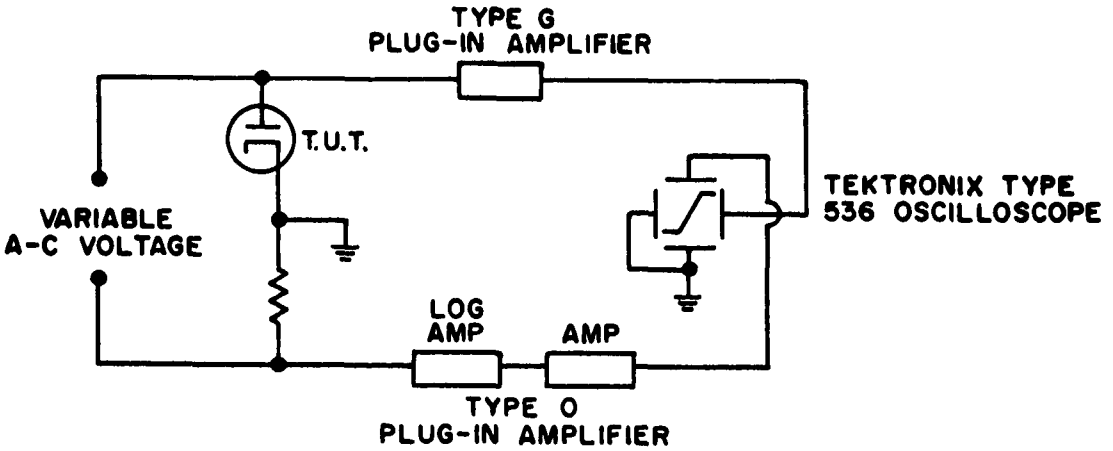
The circuit shown in Figure 1a was modified by incorporating a logarithmic amplifier. The y-amplifier plug-in unit (Tektronix Type G) in the oscilloscope was replaced with an operational amplifier plug-in unit (Tektronix Type 0) consisting of a vertical preamplifier and two operational amplifiers. The vertical preamplifier may be used either as an independent preamplifier (as in Figure 1a) or to monitor the output of either operational amplifier as in the circuit shown in Figure 2a.

The operational amplifiers may be used to perform various functions involving integration, differentiation, and amplification by adjusting the input and feedback impedances. Occasionally it is necessary to add external feedback components to supplement those mounted internally. This was necessary in order to provide a device whose output was proportional to the logarithm of the input. A practical amplifier cannot give a true logarithmic response since the logarithm of zero is infinity and hence could not handle zero input. Also, the logarithm of a negative number is not defined; therefore, a true logarithmic amplifier could not accept a negative input.

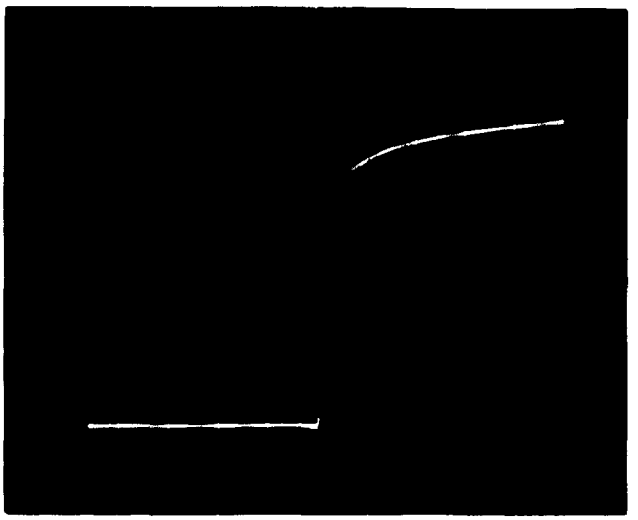
An approximate logarithmic output can be achieved with an operational amplifier circuit giving a relation between the input (e_i) and out ut (e_o) voltages as follows:

$$e_o = - \left[0.98 + (0.40 \log_{10} e_i) \right] \qquad (1)$$

This expression, obtained from the calibration curve shown in Figure 3, is logarithmic for input voltages between 0.1 and 100 volts. A typical result is shown in Figure 2b. Except for the insertion of the logarithmic amplifier in the circuit, this curve was taken under the same conditions as those of Figure 1b. With the aid of the calibration curve and the value of the viewing resistor, the y-deflection, which is a logarithmic function of voltage, may be converted to the thermionic emission of the cathode under test.



a. Circuit for Log i vs V Characteristic



b. Typical Trace Obtained Using Circuit Above

Figure 2

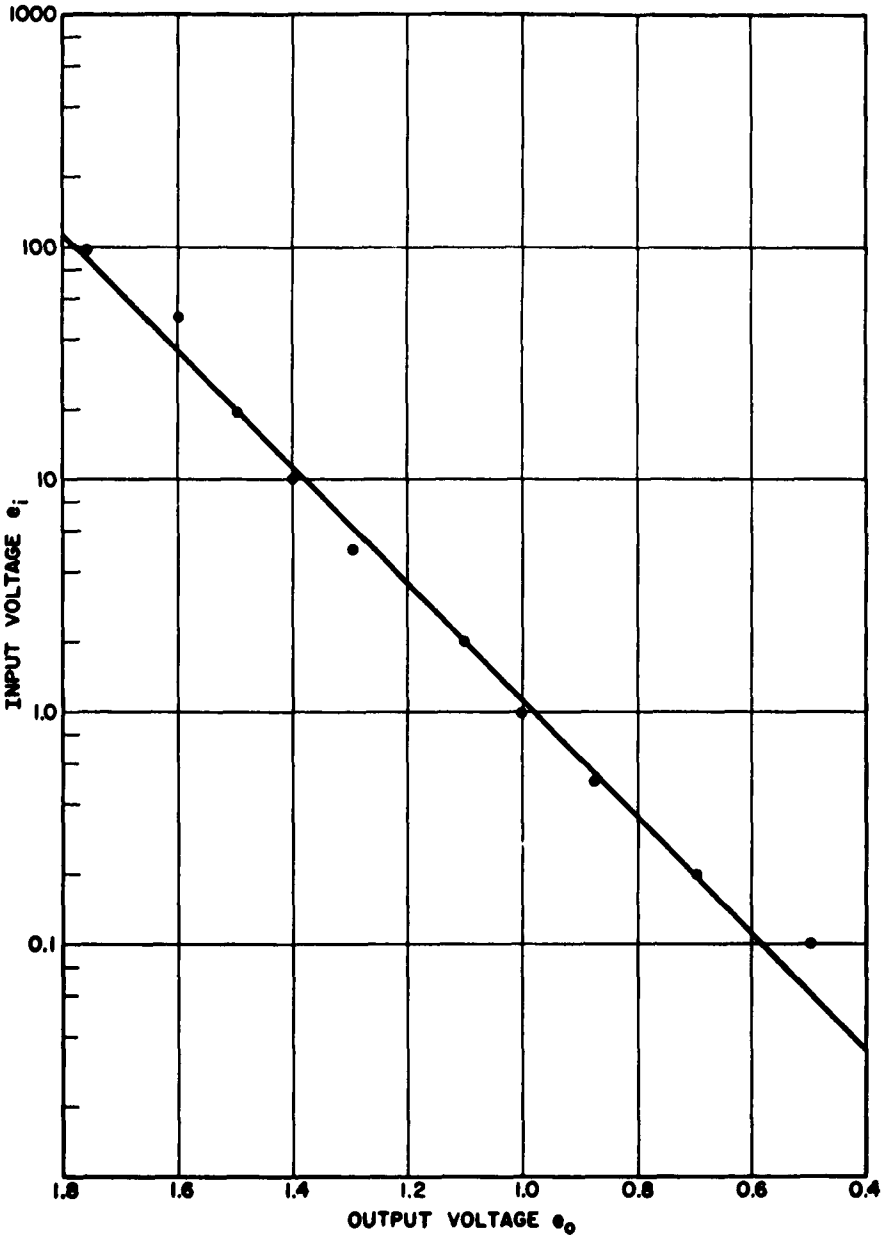


Figure 3 - Output Voltage of Logarithmic Amplifier

Using this method, measurements have been made on a barium orthosilicate dispenser cathode. Typical data is shown in Figure 4 taken at four different cathode temperatures. The work function determined from this data is:

$$\phi = 1.71 + 4.4 \times 10^{-4} T \text{ (ev)} \qquad (2)$$

This data agrees within four per cent of that taken using the point-by-point method. Although the newer technique is limited to certain voltage ranges, it does provide a rapid means for arriving at the cathode work function which should be useful in future studies of the poisoining effect of various gases on the cathode.

3. Environmental Effects

Considerable difficulty has been encountered with the Partial Pressure Analyzer (PPA) described in Scientific Report No. 3. The first problem was a small air leak whose presence was later verified by using the PPA itself as the leak detector.

The second problem was encountered while using the PPA to monitor residual gases during processing of a cathode. At the higher system pressures (5×10^{-6} Torr) seen during processing, the mass spectrum peaks tended to increase beyond a value actually representing the partial pressure of that mass. This was more pronounced on large peaks and depended on the dwell time on the peak. Moving off the peak resulted in a slow decay to base line, often masking small adjacent peaks. Using a fast sweep circuit to provide the scanning of large portions of the spectrum during a millisecond period resulted in erratic tube behavior, making an analysis impossible. The peak instability was due to damaged secondary emitter surfaces in the electron multiplier used in the PPA for the detection and amplification of a given ion species. By replacing the multiplier and rebaking the analyzer tube, mass peak stability was obtained, but the air leak seen earlier had grown in size. This limited the background pressure in the system to 6×10^{-7} Torr, too high for meaningful cathode testing.

While awaiting the replacement of the leaky analyzer tube, a similar tube and vacuum system was used to analyze the residual gases evolved during the processing of a barium calcium aluminate cathode. Prior to cathode processing, a spectrum of residual gases in

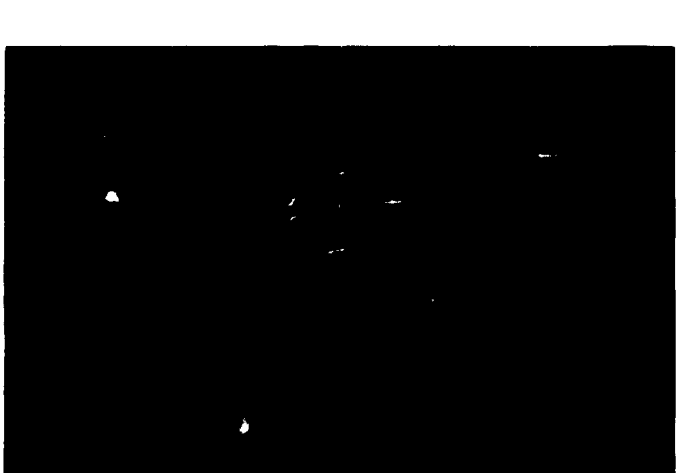


Figure 4 - Log i vs V Characteristics of a Dispenser Cathode at Four Different Temperatures

the vacuum system (total pressure = 1.1×10^{-7} Torr) showed three major constituents: H_2 at a partial pressure of 6×10^{-8} Torr, CO at $P = 4 \times 10^{-8}$ Torr, and H_2O at $P = 1 \times 10^{-8}$ Torr. During processing, only changes in the relative amounts of the major constituents were observed. Heater degassing evolved primarily H_2 at a partial pressure of 9×10^{-6} Torr with total pressure at 1×10^{-5} Torr.

During cathode activation and operating under space charge limited conditions, the partial pressures of the major components were H_2 at $P = 3.8 \times 10^{-7}$ Torr, CO and H_2O both at $P = 2.1 \times 10^{-8}$ Torr, and total pressure = 4.2×10^{-7} Torr.

When the anode voltage was increased to saturate the emission, cathode poisoning occurred. At this time, the relative amount of CO evolved definitely increased as shown by the following figures: total pressure = 8.8×10^{-7} Torr, H_2 pressure = 7.4×10^{-7} Torr, CO pressure = 1.1×10^{-7} Torr. The H_2:CO partial pressure ratio decreased from a space charge limited value of 18:1 to a poisoned cathode condition value of 7:1. This change was due to the increase in the CO.

During processing, the i-V characteristic of the cathode was also observed. Increasing the anode voltage above ten volts resulted in a definite slump in emission. This has been observed in most of the diodes tested during this program. However, this decrease occurs only during the initial processing, and subsequent heating of the anode eliminates this condition entirely. On the basis of previous work by Wargo and Shepard,[1] this phenomena is attributed to the dissociation of BaO that has been deposited on the anode, with the oxygen returning to the cathode. In an attempt to confirm this effect, special care was taken to monitor the oxygen peak as the anode voltage was varied. No meaningful change was noticed in the oxygen peak. Because of the location of the mass spectrometer with respect to the test diode and the relatively high system pressure, small changes in a given mass could occur undetected. However, the data taken did indicate an increase in the CO peak. Whether this may result in poisoning is not clear, although probably this species is only adsorbed on the anode and is liberated by electron bombardment. Additional experiments need to be performed to resolve these points.

1. P. Wargo and W. G. Shepard, Phys. Rev., Vol. 106, p. 694, 1957.

After completion of these tests, the replacement analyzer tube was received for the Partial Pressure Analyzer. During the shutdown period for the vacuum system, the zeolite in the Biondi trap was replaced by 1/8-inch diameter pellets of activated alumina. This alumina, along with the PPA, was given a normal vacuum bakeout at a temperature of 425°C. Subsequent testing of the PPA showed the same peak instability mentioned earlier.

This result rather forcibly demonstrated that special precautions must be taken during the evacuation of the Partial Pressure Analyzer. The electron multiplier contains secondary electron emitter surfaces formed by carefully controlled oxidation of alloys such as silver magnesium. The MgO film which provides the secondary emission must be limited in thickness for stable multiplier operation. One of the techniques for forming these MgO films is to heat the Ag-Mg alloy in water vapor, with pressures of 10^{-4} Torr and temperatures of 550°C being typical. This means that if multipliers are heated on vacuum systems in the presence of large amounts of water vapor, additional MgO will be formed. Malter[2] has established that oxide films, upon electron bombardment, can emit secondary electrons which reach a peak value of emission current some time after the start of bombardment and continue emitting in a decaying fashion after bombardment. If the MgO film has a high resistivity, a positive charge is built up upon electron bombardment, creating fields of such intensity that field emission is caused from the Ag-Mg and MgO. Very thin or patchy films display the field emission to a negligible degree, so no difficulty is encountered as long as the MgO thickness remains small, i.e., no water vapor in the system. An important point is to realize that the source of water vapor in the system was the activated alumina. Enough water vapor is evolved from the alumina during bakeout to raise the vapor pressure to the micron range while the multiplier dynodes are at temperatures of 425°C. Hence, MgO is likely to form and the Malter effect will occur. To eliminate this problem, the alumina trap must be baked to a temperature of 400°C while keeping the multiplier cold. This can be easily done with electrical heating tape.

Unfortunately, no convenient method is available to date for reclaiming multipliers damaged by water vapor.

PERSONNEL

Messrs. John H. Affleck and William T. Boyd contributed to the work reported herein.

2. L. Malter, Phys. Rev. Vol. 50, p. 48, 1936.

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17. Air Force Contract No. AF19(628)-279, Scientific Report No. 2, AFCRL-62-513.

18. Air Force Contract No. AF19(628)-279, Scientific Report No. 3, AFCRL-62-755.

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